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GIS-Based Landslide Susceptibility Mapping Using Frequency Ratio and AHP Methods

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ABSTRACT

In this study, the Landslide Susceptibility Map of Samsun province was produced. Slope classes, altitude classes, land use classes, soil classes, proximity to river networks classes and proximity to fault lines classes were used during the study. The Frequency Ratio method was applied to determine the relationship between the attribute classes of the parameters and the landslide events. Paired comparison matrices were created to determine the weights of the parameters and the Analytical Hierarchy method was applied. Weighted Overlay operation was applied to the classified and weighted map data using ArcMap 10.7 program. As a result of the process, the data were divided into 5 classes and the Landslide Susceptibility Map was produced.

1. INTRODUCTION

Disasters are events that can destroy the ability of the society to use its own resources, humanitarian effects, financial and economic problems, or have negative consequences and effects in the context of the environment in which they occur (Reduction, 2009).

The damage caused by disasters is analyzed in Turkey, landslides are seem to be the disasters because of loss of life and property (Ildır, 1995).

Landslides are formed as a result of the downward movement or sliding of parts such as soil and rocks, under the influence of gravity or external factors such as earthquakes and continuous rains (Afet & Başkanlığı, 2014).

The accurate and up-to-date production of landslide susceptibility maps is extremely important to prevent material and moral losses. The production process of these maps requires the evaluation and analysis of all influencing factors together (Kavas, 2009).

In this study, the Landslide Susceptibility Map of Samsun, which is located in the coordinates 41 ° 17 ′ 25 ″ N - 36 ° 20 ′01 E, was produced. Given in Fig 1.

Figure 1. Location Map

2. MATERIAL AND METHOD

In the literature, it is stated that there is no consensus among researchers about the methods and parameters used during the preparation of landslide susceptibility maps. Many parameters and methods are used because each researcher takes into account the parameters of the field she is working on (Gökçeoğlu & Ercanoğlu, 2001).

2.1. Material

The slope, elevation, land use status, soil condition, river networks and fault lines were selected as parameters for the study. The data of the material to be used in the study were mapped using ArcMap program.

Slope, elevation, land-use, river networks, soil, fault lines maps are given in Fig 2-7.

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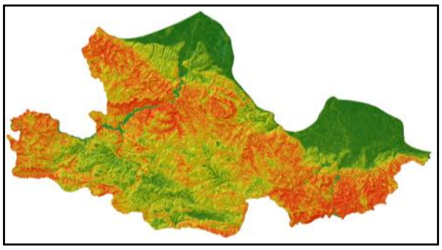

Figure 2. Slope Map

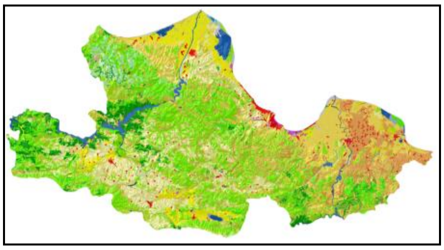

Figure 4. Land Use Map

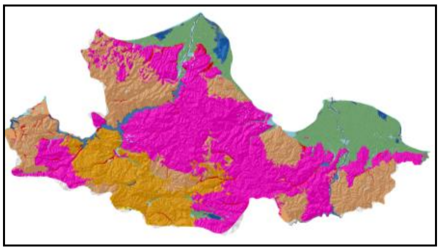

Figure 6. Soil Map

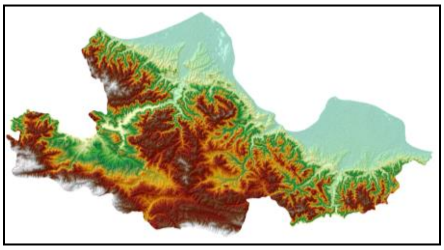

Figure 3. Elevation Map

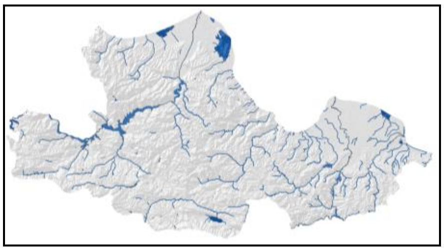

Figure 5. River Networks Map

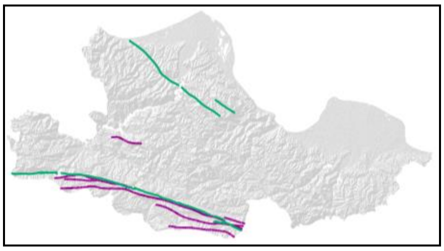

Figure 7. Fault Lines Map

2.2. Method

In the creation of the landslide susceptibility map, the values of the parameter classes were calculated with the Frequency Ratio Method (FR) by using given in Fig. 2-7 to determine the importance of the parameters and the intervals in which they affect the analysis.

A binary comparison matrix was created using the Analytical Hierarchy Method (AHP). The comparison values used in the method were determined by considering the landslide susceptibility studies and the region characteristics. Landslide Inventory Map is given in Fig 8.

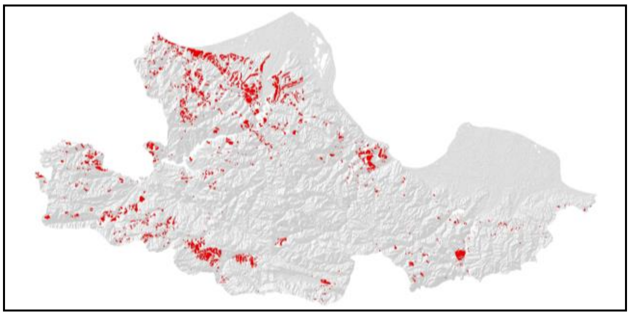

Figure 8. Landslide Inventory Map

2.2.1. Frequency Ratio Method

The Frequency Ratio (FR) method is based on density analysis. The basic principle is based on transferring all parameters to the GIS and making density analysis with the landslide inventory map (Lee & Talib, 2005).

Frequency ratio is defined as (b) / (a), where (a) corresponds to the ratio of the number of pixels with landslides in the parameter subgroup to the total number of pixels with landslides, and (b) corresponds to the ratio of the number of pixels of the parameter subgroup in the area considered, to the total number of pixels in the area under consideration (Lee & Talib, 2005).

Slope, elevation, land use, proximity to the stream, soil, proximity to fault lines classes are given in Table 1-6.

Table 1. Slope Classes

Attribute	Landslide area (% b)	Total area (% a)	Frequency ratio (b/a)
0 – 10	22,66	33,73	0,67
10 – 20	36,08	21,21	1,68
20 – 30	20,49	17,86	1,15
30 – 40	12,10	13,13	0,92
40+	8,66	13,71	0,63

Table 2. Elevation Classes

Attribute	Landslide area (% b)	Total area (% a)	Frequency ratio (b/a)
-27 – 100	13,26	21,18	0,63
100 – 400	33,26	17,83	1,86
400 – 700	21,65	23,65	0,92
700 – 1000	24,41	27,40	0,89
1000+	7,51	10,11	0,74

Table 3. Land Use Classes

Attribute	Landslide area (% b)	Total area (% a)	Frequency ratio (b/a)
Artificial areas	1,63	2,00	0,82
Agricultural areas	67,96	52,36	1,30
Forest areas	30,03	42,64	0,70
Swampy areas	0,00	1,02	0,00
Water areas	0,46	2,17	0,21

Table 4. Proximity to River Networks Classes

Attribute	Landslide area (% b)	Total area (% a)	Frequency ratio (b/a)
0 – 500	3,29	6,86	0,48
500 – 1000	3,98	4,62	0,86
1000 – 2000	10,98	10,44	1,05
2000 – 3000	13,52	10,96	1,23
3000+	68,31	67,31	1,01

Table 5. Soil Classes

Attribute	Landslide area (% b)	Total area (% a)	Frequency ratio (b/a)
Class A	1,64	2,31	0,71
Class B	22,57	23,88	0,94
Class C	18,30	13,75	1,33
Class D	1,25	1,40	0,89
Class E	0,00	0,09	0,00
Class F	0,00	0,94	0,00
Class G	0,83	14,18	0,06
Class H	0,03	0,06	0,44
Class I	55,19	41,39	1,33

Table 6. Proximity to Fault Lines Classes

Attribute	Landslide area (% b)	Total area (% a)	Frequency ratio (b/a)
0 – 1000	16,38	7,02	2,40
1000 – 2500	13,97	6,87	2,03
2500 – 5000	14,27	8,62	1,66
5000 – 10000	19,14	17,57	1,09
10000+	35,67	60,12	0,59

2.2.2. Analytical Hierarchy Process

The Analytical Hierarchy Method (AHP) was developed by L. Saaty in 1977 as a model that will enable the solution of multi-parameter decision making problems (Kavzoğlu, Şahin, & Çölkesen, 2012).

Priority and weight vectors are calculated by normalizing the pairwise comparison matrix. Therefore, the elements in the columns of the matrix are divided by the sum of each column to form a normalized pairwise comparison matrix. The row elements in the new matrix are summed and the value obtained as a result of the sum is divided by the number of elements in the row. In this way, a weight vector or priority vector is created (Kavas, 2009; Tombuş, 2005).

Weights take a value between 0 and 1 and their sum equals 1 (Malczewski, 1999; Öztürk & Batuk, 2010). The weights of this study are given in Table 7.

Table 7. Map Weights

	a	b	c	d	e	f	Weights
a	1						% 17,20
b	1,00	1					% 16,60
c	0,50	0,33	1				% 9,10
d	2,00	2,00	2,00	1			% 22,40
e	0,50	0,50	1,00	0,50	1		% 9,50
f	1,00	2,00	2,00	2,00	2,00	1	% 25,20

a. slope, b. height, c. land use status, d. soil, e. proximity to river networks, f. proximity to fault lines

The weight of the parameters was calculated after the comparison matrix. The consistency ratio was found as CR = 0.039. Since the ratio we obtained was below 0.10, which is the highest value determined for the correct execution of the study, there was no need to repeat the pairwise comparison method (Wind & Saaty, 1980).

3. RESULTS

The parameters to be used in the field of study were determined. The data of the parameters were mapped with the help of Geographical Information Systems.

The maps were weighted by using the Frequency Ratio Method (FR) by calculating the areal rates associated with the landslide inventory map. The data pixels have been reclassified according to their weight.

The weights of the parameters relative to each other were determined using the AHP.

A susceptibility map was produced by applying the weighted registration process. The map produced was reclassified 5 as very low, low, medium, high and very high. Landslide susceptibility map is given in Fig 8.

4. DISCUSSION

It was realizen an investigation in the produced landslide susceptibility map with map classes.

Although it was seen that landslides could occur in every class, the highest risk interval was determined as the range of 10-20 degrees with 19.54% in Slope Classes.

When the altitude classes are examined, it was seen that landslide events are less in the range of 0-100 meters. The highest risk interval was determined as the range of 700-1000 meters with 18.56%.

While it was observed that landslide events were less in artificial areas, swampy areas and water areas in the land use classes, the highest risk areas were determined as agricultural areas with a rate of 36.80 %.

In the soil classes, it was observed that landslide events were less in colluvial soil, red yellow podzolic soil, hydromorphic soil, alluvial soil and brown soil classes. The highest risk soils were determined to be brown forest soils with a rate of 32.39 %.

When the proximity to river networks classes are examined it was found that the rate of landslides in each class, although the parameter is not distinctive for the study area.

For the proximity to fault lines classes, it was observed that landslide events are less in areas more than 10 kilometers away. The highest risk range has been determined as the 5-10-kilometer range with 13.85 %.

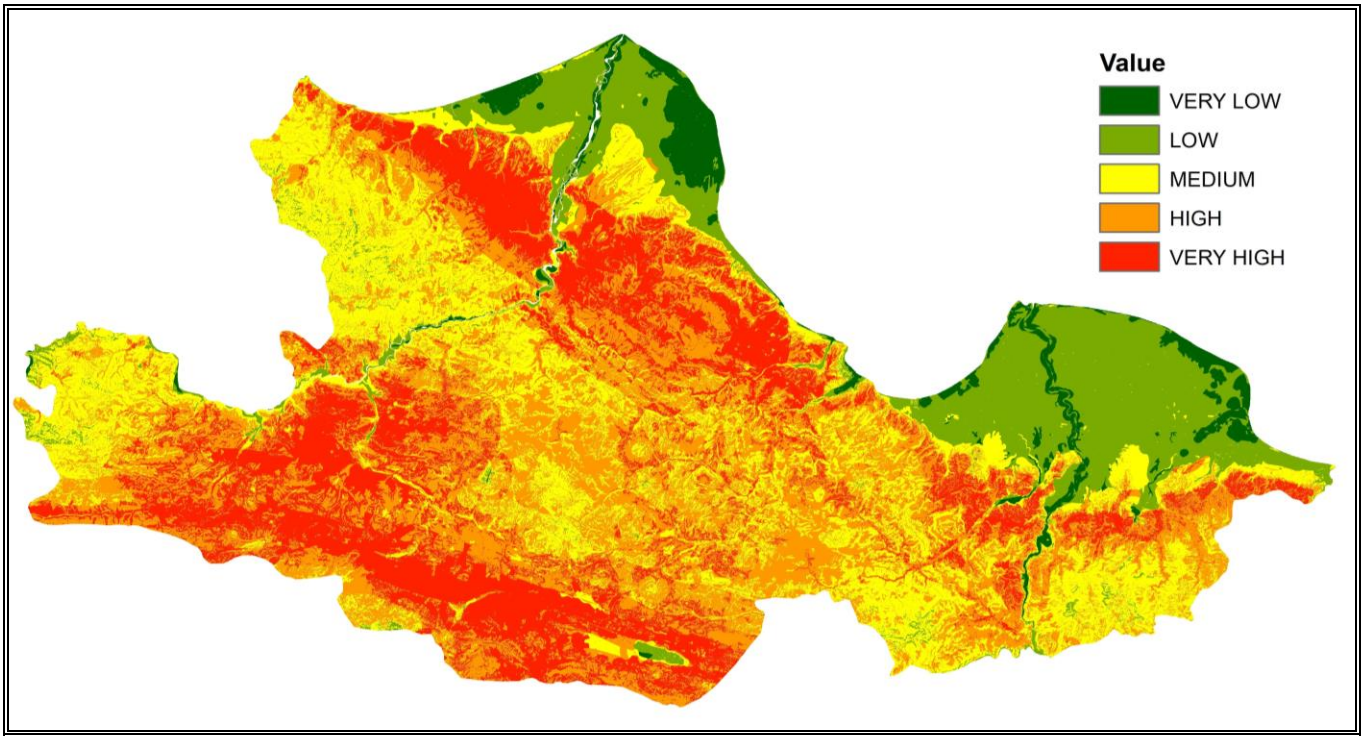

Figure 8. Landslide Susceptibility Map

5. CONCLUSION

The areas and rates of the landslide susceptibility classes are given in Table 8.

Table 8. Landslide Susceptibility Classes

Attribute	Landslide area (km^2)	Total area (km^2)	Landslide incident (%)	Total area (%)
Very Low	0,04	332,59	0,01	3,50
Low	3,57	1280,23	0,95	13,47
Medium	64,25	2364,19	17,01	24,88
High	114,29	3381,41	30,27	35,58
Very High	195,46	2144,45	51,76	22,57

When susceptibility classes are examined it was seen that 82.03% of the old landslide events occurred in high and very high class, 17.01% occurred in middle class and 0.96% occurred in low and very low class.

In the spatially analysis of landslide events, it was seen that the sensitivity classes are examined spatially, high-risk areas constitute 58.15% of all areas, medium-risk areas constitute 24.88% of all areas and low-risk areas constitute 16.97% of all areas.

Landslide susceptibility maps are of great importance in predicting future landslides and ensuring land use planning.

As a result, it is possible to say the following. Risk analysis methods should definitely be used in order to prevent future financial and moral losses caused by landslides that occur in different spatial structures.

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